California Industrial Energy Efficiency Potential

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ABSTRACT

This paper presents an overview of the modeling approach and highlights key findings of a California industrial energy efficiency potential study. In addition to providing estimates of technical and economic potential, the study examines achievable program potential under various program-funding scenarios. The focus is on electricity and natural gas savings for manufacturing in the service territories of California's investor-owned utilities (IOUs).

The assessment is conducted by industry type and by end use. Both crosscutting technologies and industry-specific process measures are examined. Measure penetration into the marketplace is modeled as a function of customer awareness, measure cost effectiveness, and perceived market barriers. Data for the study comes from a variety of sources, including: utility billing records, the Energy Information Association (EIA) Manufacturing Energy Consumption Survey (MECS), state-sponsored avoided cost studies, energy efficiency program filings, and technology savings and cost data developed through Lawrence Berkeley National Laboratory (LBNL).

The study identifies 1,706 GWh and 47 Mth (million therms) per year of achievable potential over the next twelve years under recent levels of program expenditures, accounting for 5.2% of industrial electricity consumption and 1.3% of industrial natural gas consumption. These estimates grow to 2,748 GWh and 192 Mth per year if all cost-effective and achievable opportunities are pursued. Key industrial electricity end uses, in terms of energy savings potential, include compressed air and pumping systems that combine to account for about half of the total achievable potential estimates. For natural gas, savings are concentrated in the boiler and process heating end uses, accounting for over 99 % to total achievable potential.

Background

California has recently specified very aggressive electricity and natural gas energy efficiency targets for its investor-owned utilities (CPUC 2004). In order to meet these targets, it is likely programs that have been traditionally targeted at the residential and commercial sectors will need to expand to better address energy saving opportunities in the industrial sector. This expansion will require program planners to have a better understanding of which industries and end uses to focus program efforts.

Initial industrial sector energy efficiency potential work for California consisted of an Industrial Market Characterization Study (XENERGY 2001) that relied on secondary source data to organize and segment industrial energy use and identify primary energy efficiency opportunities, and a statewide electricity efficiency potential study (XENERGY 2002) that addressed industrial potential in a highly aggregated analysis.

This current study builds upon these past analyses and provides a more comprehensive and detailed set of energy efficiency potential estimates for use by program planners and policy makers. The focus of the current effort is on electricity and natural gas savings for manufacturing in the service territories of California's investor-owned utilities (IOUs).

Study Approach

The assessment of industrial energy efficiency potential was developed using a bottom-up methodology. For non-process end uses (lighting and HVAC), equipment-specific measures (such as high efficiency chillers and T8 fluorescent lighting with electronic ballast) were included in the analysis. Costs and savings for these measures, relative to a base technology, were developed and used to determine available savings potential and measure cost effectiveness. For process end uses, measures were more generalized (equipment efficiency improvements, controls, process redesign, etc.) and approximate savings percentages, measure applicability, and cost per unit saved were developed by LBNL based on a compilation of industry-specific secondary-source research. A complete list of references is contained in the report that this paper draws from (KEMA & LBNL 2005). Table 1 lists the measures investigated in the study.

Our industrial potential analysis includes estimates of several types of potential common to such studies. The potentials estimated and our definitions for them are as follows: **Technical potential** is defined as the complete penetration of all measures analyzed in applications where they were deemed technically feasible from an engineering perspective. **Economic potential** refers to the technical potential of those energy conservation measures that are cost effective when compared to supply-side alternatives, using the total resource benefit-cost (TRC) test. The TRC ratio is calculated as the net present value of the supply-side costs avoided by the demand-side resource option (including energy and delivery costs) divided by the net present value of the total costs of the demand-side option, including both the participants' costs and the utility's/implementer's costs (including equipment, installation, operation and maintenance, and program administration costs) (CPUC 2001). A TRC ratio greater than or equal to 1.0 indicates that a demand-side resource option is cost effective.

Achievable potential refers to the amount of savings that would occur in response to specific program funding and measure incentive levels. Savings associated with program potential are savings that are projected beyond those that would occur naturally in the absence of any market intervention. (Maximum achievable potential is defined as the amount of economic potential that could be achieved over time under the most aggressive program scenario possible.) **Naturally occurring** potential refers to the amount of savings estimated to occur as a result of normal market forces, that is, in the absence of any utility or governmental intervention. Naturally occurring potential is far less than economic and achievable potential because a host of market barriers limit measure adoption to levels below those that are cost-effective as compared to the costs of supply. Achievable potential incorporates programmatic costs that directly or indirectly mitigate market barriers and result in net increases in measure adoptions (i.e., net adoptions above and beyond naturally occurring levels). Specific achievable potential scenarios are described below.

The analysis involves carrying out a number of basic analytical steps to produce estimates of the energy-efficiency potentials introduced above. The bulk of the analytical process for this work was carried out in a model, DSM ASSYST™, developed by KEMA (formerly XENERGY) for conducting energy-efficiency potential studies. The model integrates technology-specific engineering and customer behavior data with utility market saturation data,

Table 1. Measures Addressed in the Industrial Energy Efficiency Potential Study

Electricity		Natural Gas	
End Use	**Measure**	**End Use**	**Measure**
HVAC	High Efficiency Chillers	HVAC	Improve Ceiling Insulation
	High Efficiency DX AC		Duct Insulation
	Cooling System Tuneups		Install High Eff (95%) Condensing Furnace/Boiler
	Window Film		Stack Heat Exchanger
	Energy Mgmt System (EMS)		EMS Install
	Programmable Thermostat		EMS Optimization
	Evaporative Precoolers	Boilers	Flue Gas Heat Recovery/Economizer
Lighting	T8 - Elec. Ballast Lighting		Blowdown Steam Heat Recovery
	Compact Fluorescent Lamps		Upgrade Burner Efficiency
	Metal Halide Lighting		Water Treatment
	Lighting Controls		Condensate Return
Process	Premium Efficiency Motors		Improved Insulation
	Adjustable Speed Drives		Improved Process Control
	Motor Efficiency Practices		Load Control
	O&M (Pumps, Fans, Comp. Air)		Maintain Boilers
	Controls (Pumps, Fans, Comp. Air)		Steam Trap Maintenance
	System Optimization (Pumps, Fans, Comp. Air)		Automatic Steam Trap Monitoring
	Sizing (Pumps, Fans, Comp. Air)		Leak Repair
	Replace V-belts	Process Heating	Heat Recovery
	Air Conveying Systems		Efficient Burners
	Efficient Drives		Efficient Drying
	Process Control (by Industry and End Use)		Closed Hood
	Process Optimization (by Industry and End Use)		Extended Nip Press
	Refinery Controls		Improved Separation Processes
	Clean Room - Controls		Thermal Oxidizers
	Optimize Drying Process		Efficient Furnaces
	Heating - Scheduling		Oxyfuel
	Drives - Scheduling		Batch Cullet Preheating
	Gap Forming Paper Machine		Insulation/Reduce Heat Losses
	High Consistency Forming		Process Controls & Management
	Efficient Practices Printing Press		Process Integration
	Efficient Printing Press (Fewer Cylinders)		Flare Gas Controls And Recovery
	Light Cylinders		Fouling Control
	Clean Room - New Designs		Combustion Controls
	Drying (UV/IR)		Optimize Furnace Operations
	Heat Pumps for Drying		Preventative Maintenance
	Extruders/injection Molding-Multipump		
	Direct Drive Extruders		
	Injection Molding - Impulse Cooling		
	Injection Molding - Direct drive		
	Efficient Grinding - Cement		
	Bakery - Process Improvements		
	Top-heating (Glass)		
	Efficient Electric Melting		
	Intelligent Extruder (DOE)		
	Near Net Shape Casting		
	Efficient Curing Ovens		
	Efficient Refrigeration - Operations		
	Efficient Desalter		
	New Transformers Welding		
	Other Efficient Machinery - Industry Specific		
	Bakery - Process (Mixing) - O&M		
	O&M / Drives Spinning Machines		
	O&M - Extruders/Injection Molding		
All	Power recovery		
	Energy Star Transformers		

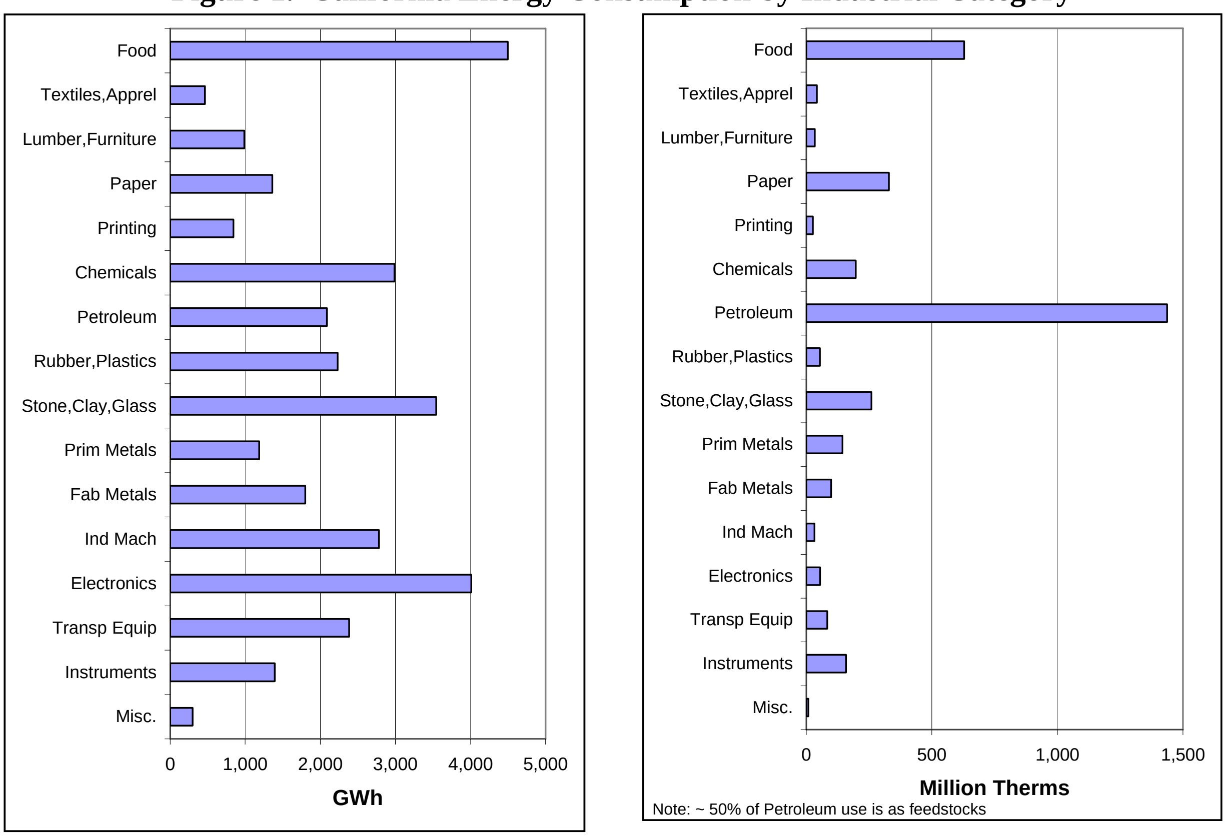
Note: Measure attributes vary by industry type.

load shapes, rate projections, and marginal costs into an easily updated data management system. A supply curve approach is used to estimate technical and economic potential, with measure sorting and economic potential defined by the TRC test. Using the TRC is advantageous because the value of both energy and peak demand savings are incorporated into the analysis. The adoption modeling approach uses a two-step process in which end users must be aware and knowledgeable about each efficiency opportunity before adopting it and, once aware, adopt at a market share level determined by the economic attractiveness of the measure and level of market barriers associated with it. For a more detailed description of the modeling approach used for the analysis, see KEMA & LBNL 2005.

Industrial Baseline Usage

A key initial step in the analysis was to develop a baseline understanding of industrial electricity and natural gas consumption in the California IOU service territories. Billing consumption data from the IOUs were combined with 1998 MECS data (EIA 1998) to provide usage estimates by industry type and end use. For electricity, the motors end use was further broken down by application (pumps, fans, compressed air, other) using information from the DOE Motors Assessment Study (XENERGY 1998). Figures 1 shows the composition of electricity and natural gas consumption by industry segment and Figure 2 summarizes consumption by key end use.

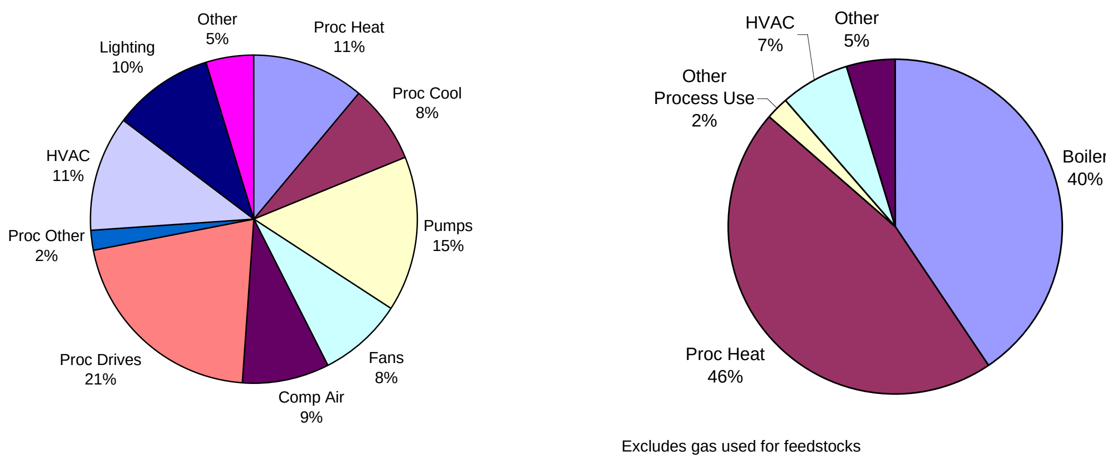
Figure 1. California Energy Consumption by Industrial Category



Electricity **Natural Gas**

Source: California utility billing records.

Figure 2. California Industrial Energy Consumption by End Use



Electricity **Natural Gas**

Source: KEMA/LBNL analysis of 1998 MECS and utility billing records.

Program Funding Scenarios

Two energy efficiency program-funding scenarios were developed in the study. The base scenario assumes a continuation of utility and third-party programs at current levels of funding (for 2004-2005 program years). A second scenario examines potential energy efficiency impacts under "maximum achievable" program effort. This second scenario assumes payment of incentives that cover 100% of incremental measure cost (ramped up from current incentive levels to 100% by 2007) and increased marketing and customer education budgets such that the majority of customers are informed about energy efficiency opportunities, based on past experience with program marketing/education effectiveness. Table 2 summarizes the program funding scenarios.

Table 2. Summary of California Industrial Program Funding Scenarios

Funding Scenario	Program Budget Components				% of Measure Cost Paid*
	Administration	Marketing	Incentives	Total	
Electricity					
Base	$5.2	$12.7	$16.1	$34.0	60%
Maximum Achievable	$7.1	$15.9	$54.4	$77.4	100%
Natural Gas					
Base	$1.3	$1.7	$2.1	$5.1	50%-70%
Maximum Achievable	$8.6	$5.7	$14.9	$29.3	100%

The percent of incremental measure cost paid in the form of incentives. Incentives are not paid on equipment maintenance measures.

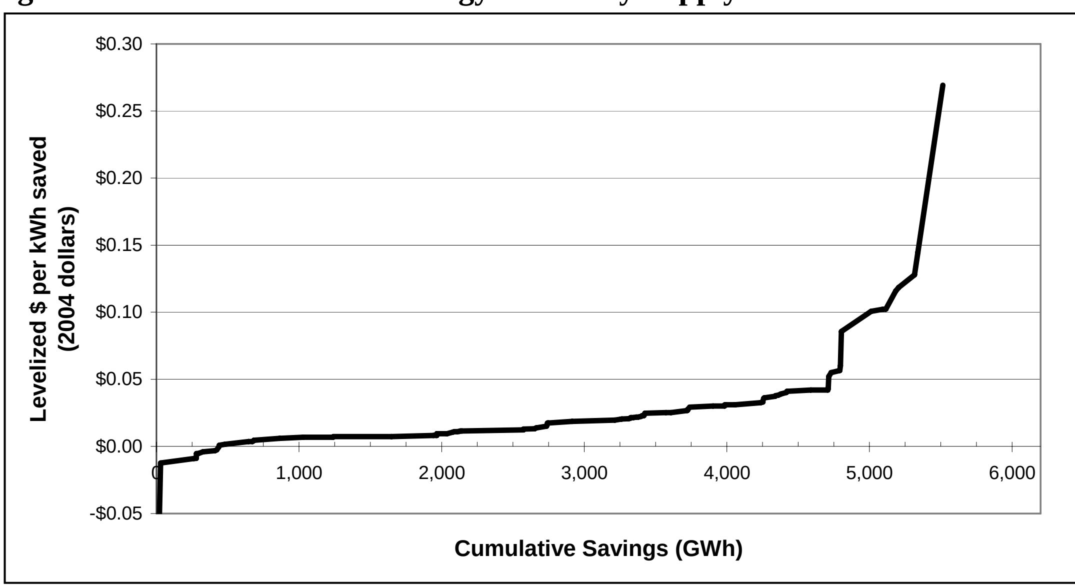
Note that assumed funding levels increase a little over two-fold between the base and maximum achievable scenarios for electricity, while the increase is almost six-fold for natural gas. One of the factors contributing to this difference is the advanced level of spending in California of electricity efficiency in response to the energy crisis of 2001.

Results

If all the electric measures that were included in the study were implemented where *technically* feasible, savings are estimated to be about 5,500 GWh per year and 750 MW of peak demand. Similarly, potential savings for natural gas are estimated to be about 470 Mth (million therms). These technical potential savings amount to about 17% of base electricity use and 13% of base gas use. If measure implementation were restricted to all measures that were determined to be *economically* viable, electric savings potential would be about 5,000 GWh per year and 660 MW, and natural gas savings potential would be about 470 Mth (similar to technical potential because the measure list in the study was limited to the more economic measures). The economic potential savings are about 15% of base electricity use and 13% of base gas use. It should be noted that the electricity potential results are lower than those published several years ago (XENERGY 2002). A key factor contributing to the lower estimates is this study's focus on the manufacturing sector of the IOU service territories versus an earlier focus on an expanded industrial sector (including mining and transportation, communication and utilities market segments) for the entire state.

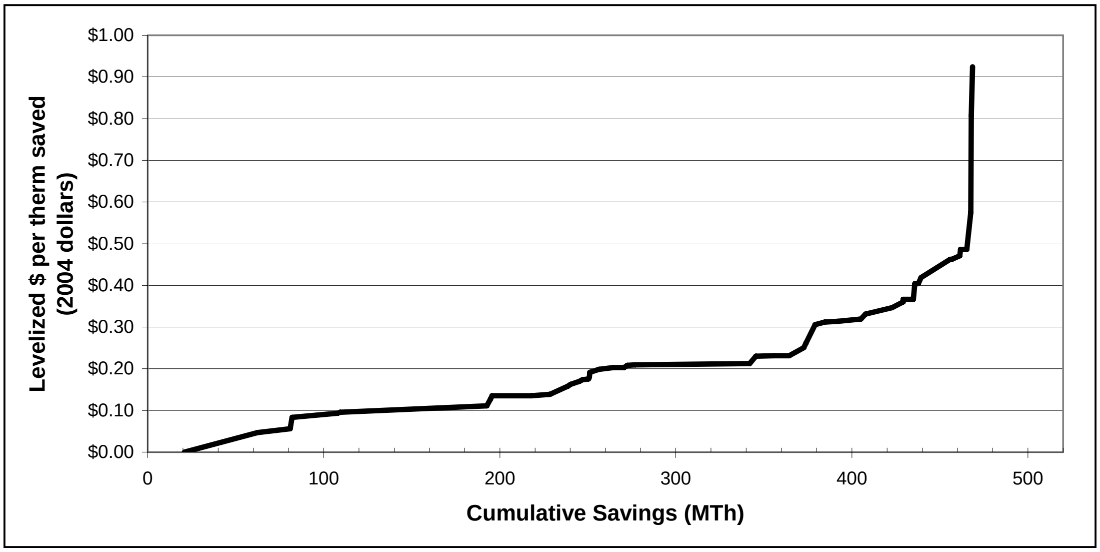
A typical way to illustrate the amount of energy efficiency savings available at various costs is with energy efficiency supply curves. These are shown in Figures 3 and 4 for electricity and natural gas, respectively. As shown, a considerable portion of potential savings is estimated to be achievable at fairly low costs (below $0.05 per kWh and $0.50 per therm). Costs begin to increase dramatically at the edges of the supply curves. Note that negative costs associated with some electricity measures result because of predicted operations and maintenance (O&M) savings that are attributable to these measures.

Figure 3. California Electric Energy Efficiency Supply Curve for Manufacturing



Source: KEMA/LBNL analysis.

Figure 4. California Natural Gas Energy Efficiency Supply Curve for Manufacturing



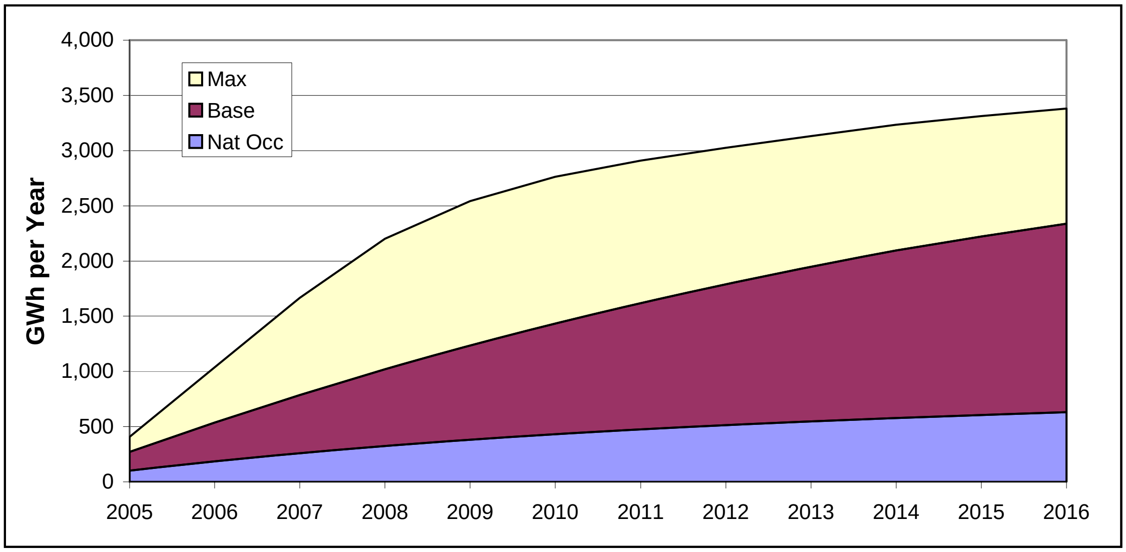
Source: KEMA/LBNL analysis.

Achievable Potential

Integrating economically viable measure information with customer acceptance parameters and program funding estimates provides a forecast of achievable program potential. The potential program accomplishments are estimated incremental to naturally occurring savings. Figures 5 and 6 show achievable potential estimates through 2016 for electricity and natural gas, respectively. For electricity, cumulative net program savings by 2016 range from about 1,700 GWh per year under the base program-funding forecast to 2,700 GWh under the maximum achievable forecast. For natural gas, cumulative net savings by 2016 range from about 47 Mth (base scenario) to 190 Mth (maximum achievable scenario).

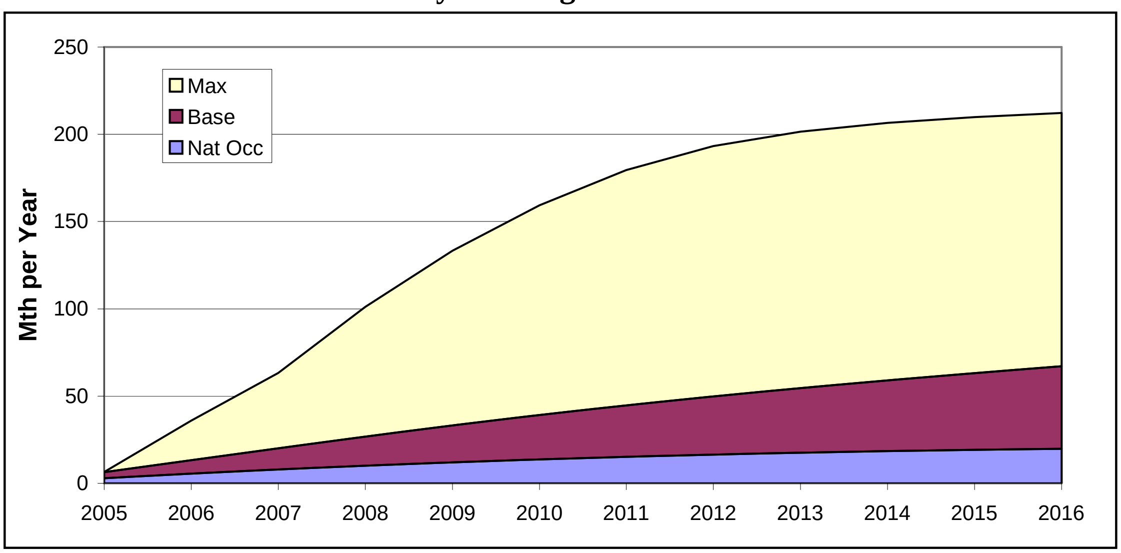
For both electricity and natural gas projections, the base forecast shows steady growth in cumulative savings over time, while the maximum achievable forecast indicates a quick ramp up in program accomplishments, followed by a leveling off of savings as measures begin to reach market saturation levels. The very quick ramp up in the maximum achievable scenario reflects a modeling response to a very aggressive program escalation forecast. While longer-term accomplishments under this scenario may be achievable, it is not clear that market dynamics could accommodate such a rapid program expansion, due to factors such as the availability of qualified program staff and implementation personnel. Also, if a maximum achievable approach is pursued in California, there will be an additional need to focus more resources on bringing along commercially viable emerging technologies to replace the current mix of available measures, since these current technologies will begin to reach maximum saturation levels.

Figure 5. Potential California Industrial Electricity Efficiency Savings by Funding Scenario



Source: KEMA/LBNL analysis.

Figure 6. Potential California Industrial Natural Gas Efficiency Savings by Funding Scenario

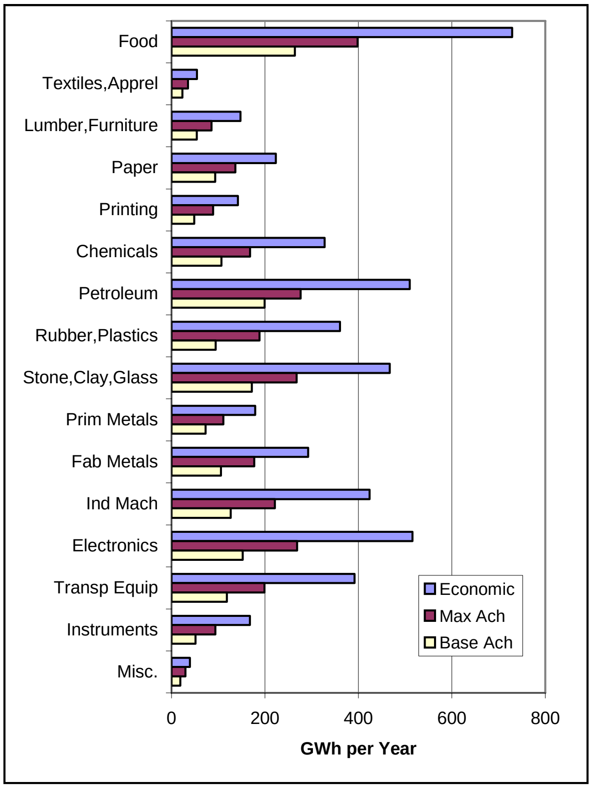


Source: KEMA/LBNL analysis.

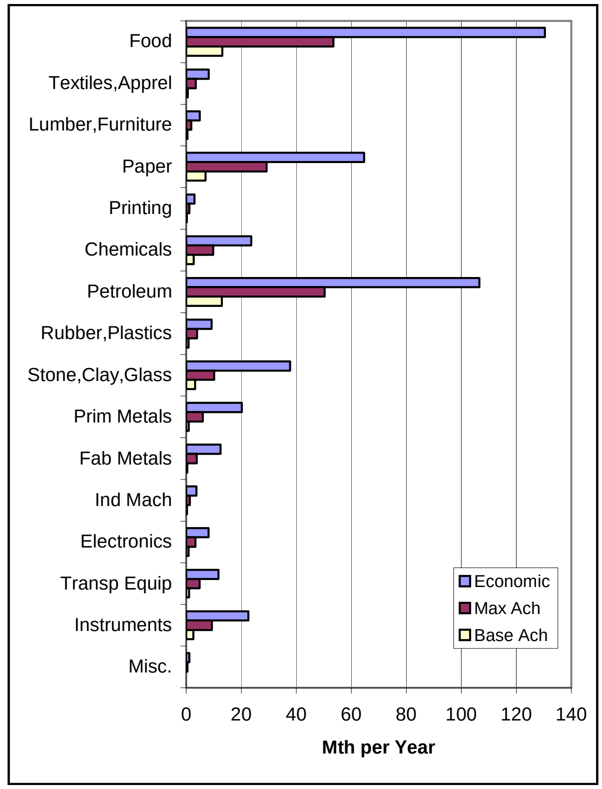
The difference between base and maximum achievable potential is much narrower for electricity, due to recent program expansion in response to California's 2001 energy crisis and a concentrated effort by California policy makers to expand electricity efficiency efforts. For natural gas, the maximum achievable forecast reflects a considerable stretch above current program levels. Given the large variation between the base and maximum achievable gas scenarios, one must recognize that there is uncertainty in the maximum achievable forecast, because it is the result of model-based predictions that are beyond historic experience with regard to levels of program funding and implementation effort.

Figure 7 shows, by industry group, cumulative achievable savings projects in 2016 in comparison to total economic potential. For electricity, savings potential is distributed fairly well across industrial groups, with Food, Petroleum, Stone/Clay/Glass, Industrial Machinery, and Electronics showing the most potential. For natural gas, savings potential is most concentrated in the Food, Paper, and Petroleum industrial segments.

Figure 7. Potential California Energy Savings by Industry Group - 2016



Electricity



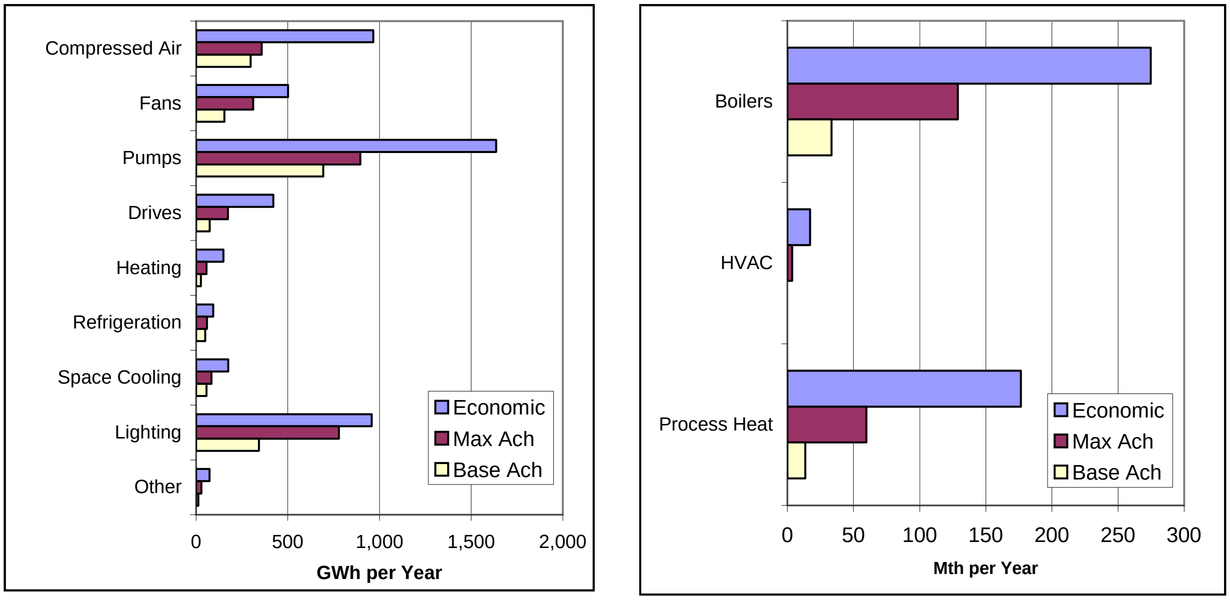
Natural Gas

Source: KEMA/LBNL analysis.

Potential savings by end use are displayed in Figure 8. For electricity, pump systems, compressed air systems, fan systems, and lighting show the largest potential. Recent work has indicated that the penetration of T8 lighting in the industrial sector is much lower than that of the commercial sector (Aspen 2003). While programs targeting compressed air have been initiated in California over the past several years, pumping and fan systems have received less attention.

For natural gas, savings potential is concentrated in the boiler and process heating end uses where most of the natural gas consumption takes place. Given the relative similarity in boiler efficiency measures across industrial groups, it is likely that these measures will be easier to implement. The heterogeneous nature of the process heating measures will make implementation more complicated and will require more efforts at customer education.

Figure 8. Potential California Industrial Energy Savings by End Use - 2016



Electricity **Natural Gas**

Source: KEMA/LBNL analysis.

Table 3 shows the top 15 electricity and natural gas measures, based on their contribution to base achievable potential by 2016. For both electricity and natural gas, improved process controls, system optimization, and O&M measures are key components of potential savings. These are types of measures that will require continued customer information and education efforts to facilitate increased measure adoption.

Table 3. Top 15 Electricity and Natural Gas Industrial Measures for California

Electricity Measures	% Base Achievable	Natural Gas Measures	% Base Achievable
Pumps - System Optimization	24.2%	Improved boiler insulation	35.0%
T8 Lighting	12.8%	Load control - boilers	26.3%
Pumps - Controls	7.5%	Process Controls & Mgmt – proc heat	24.0%
Compressed Air - System Optimization	7.0%	Maintain boilers	4.2%
CFLs	5.2%	Fouling control - proc heating	3.7%
Pumps - ASD (100+ hp)	4.7%	Improved process control - boilers	2.8%
Optimization - Refrigeration	3.5%	Automatic steam trap monitoring	1.4%
Fans - System Optimization	2.9%	Water treatment - boilers	1.2%
Comp Air - ASD (100+ hp)	2.7%	Process integration - proc heat	0.5%
Compressed Air-O&M	2.4%	Heat Recovery - proc heat	0.2%
Pumps - O&M	2.3%	Efficient burners - proc heat	0.1%
Fans - ASD (100+ hp)	2.2%	Optimize furnace operations – proc heat	0.1%
Compressed Air- Sizing	1.6%	Improve ceiling insulation - HVAC	0.1%
Fans - Controls	1.4%	EMS installation - HVAC	0.07%
Pumps - Motor practices-1 (100+ HP)	1.3%	EMS optimization – HVAC	0.07%
Top 15 Total	81.9%	Top 15 Total	99.7%

Source: KEMA/LBNL analysis.

Table 4 summarizes the benefit-cost estimates for the achievable program scenarios. As shown, the program scenarios all have estimated TRC ratios that are greater than one, indicating program cost effectiveness. For electricity, net benefits are estimated to be $0.9 billion for the base scenario and $1.3 billion for the maximum achievable scenario. For natural gas, net benefits are estimated to be $0.4 billion for the base and $1.3 billion for the maximum achievable scenario. The benefit and cost estimates reflect the assumption that all estimated potential savings can be captured with the estimated program and measure cost outlays. There is uncertainty regarding the estimated relationships between costs, impacts, and associated benefits as we extent out into the forecast period. This uncertainty is greatest for the maximum achievable scenario as it is a considerable extension beyond recorded program experience.

Table 4. Summary of Net Achievable Industrial Potential Results for California (2005-2016)

	Electricity		**Natural Gas**	
Result	**Base**	**Max**	**Base**	**Max**
Program Costs (Mil.)	$317	$770	$48	$275
Participant Costs (Mil.)	$285	$247	$24	$61
Avoided Cost Benefits (Mil.)	$1,523	$2,353	$497	$1,608
Net Benefits (Mil.)	$921	$1,336	$426	$1,271
Net Savings	1,706 GWh/Yr 216 MW	2,748 GWh/Yr 378 MW	47 Mth/Yr	192 Mth/Yr
Program TRC Ratio	2.5	2.3	7.0	4.8

Present value of benefits and costs over 20-year normalized measure lives for 12 program years (2005-2016), nominal discount rate of 8%, inflation rate of 3%; energy savings are cumulative.

Conclusions

This industrial potential study should help program planners better target the industrial market as it provides results by industry type and by end use and key measures. Achievable energy savings range for 5% to 8% of base usage for electricity and from 1% to 5% of base usage for natural gas. The achievable program estimates fall below economic potential estimates because it is unlikely that programs will be able to capture all the available savings due to factors such as naturally occurring savings, limited equipment turnover during the forecast period, and the fact that some customers will not install cost-effective measures due to various market barriers (such as capital limitations, lack of information about measures, limited installation opportunities due to production schedules, and hassle). All forecast program scenarios have projected TRC ratios greater that 1.0, reflecting our estimates that program benefits will exceed costs.

For electricity, the cumulative energy savings for the maximum achievable forecast are about 60% higher that the base forecast (that reflects current program efforts) by 2016. For natural gas, the maximum achievable forecast is about 300% above the base forecast. The differences between electricity and natural gas projections reflect the fact that California has pursued electricity efficiency options more rigorously that it has pursued natural gas options. There is also more uncertainty in the maximum achievable forecasts, since they reflect program efforts that are considerably beyond historical experience. This is especially true for the natural gas efficiency projections.

For both electricity and natural gas, improved process controls, system optimization, and O&M measures are key components of potential savings. These measures are likely to be more difficult to implement than strict equipment efficiency improvements, as they will require more customer education to effect improvements. A key component of forecast uncertainty is related to customer adoption of the control and optimization measures.

Acknowledgments

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